US006005854A

United States Patent [19]

Xu et al.

[11] Patent Number: 6,005,854

[45] Date of Patent: Dec. 21, 1999

[54] SYNCHRONOUS WIRELESS ACCESS PROTOCOL METHOD AND APPARATUS

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[21] Appl. No.: 08/908,914

[22] Filed: Aug. 8, 1997

[51] Int. Cl.[6] H04J 13/00

[52] U.S. Cl. 370/335; 370/350

[58] Field of Search 370/312, 328, 370/329, 335, 336, 337, 342, 345, 347, 350, 441, 442, 443, 503, 515; 455/575, 450, 509, 517

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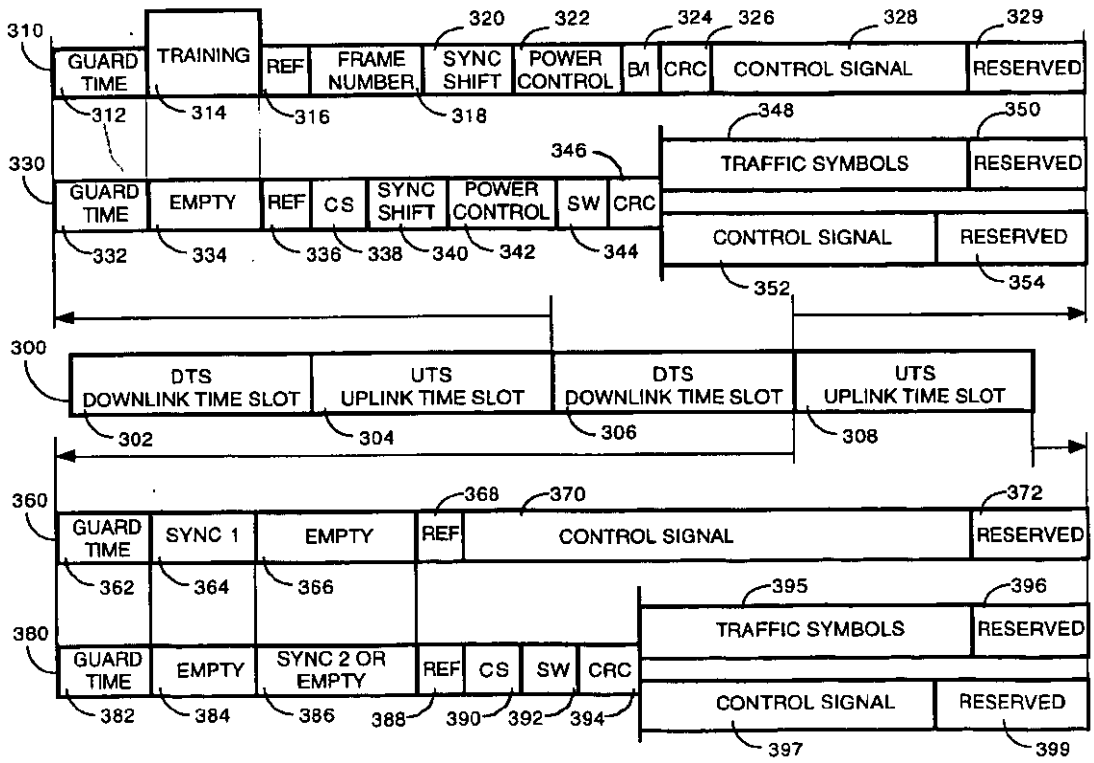
Primary Examiner—Huy D. Vu
Attorney, Agent, or Firm—Michael J. DeLuca

[57] ABSTRACT

A wireless communication system has a protocol enabling synchronous code division multiple access (CDMA) communication on a time division duplex (TDD) frequency, and provides for a smart antenna system as an integral component of the system. The protocol has downlink time slots (DTS) which provide for synchronization and paging of all remote terminals from a base station on a omnidirectional code channel and while providing for traffic signals on directional traffic channels. The protocol has uplink time slots (DTS) which enable rapid link requests by remote terminals, as well as enabling improved spacial estimation, synchronization and power control of remote terminals by the base station.

13 Claims, 10 Drawing Sheets



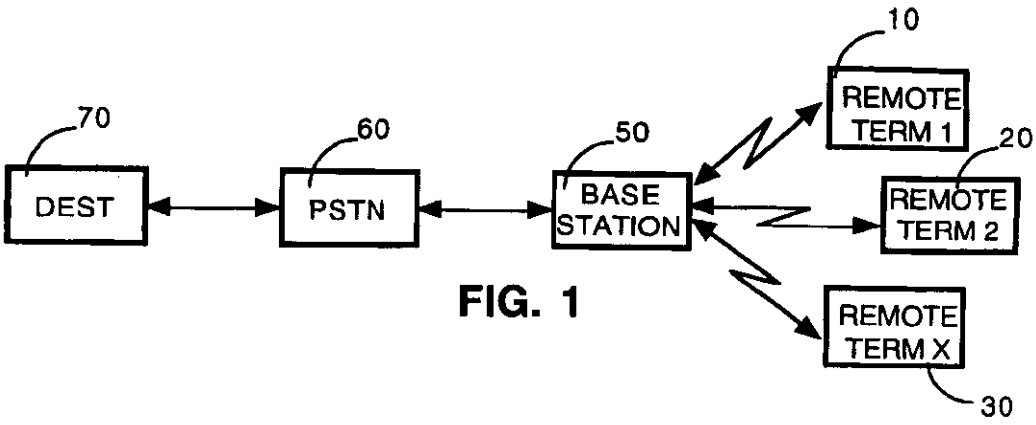

10
REMOTE TERM 1
20
REMOTE TERM 2
REMOTE TERM X
30
70
DEST
60
PSTN
50
BASE STATION

FIG. 1

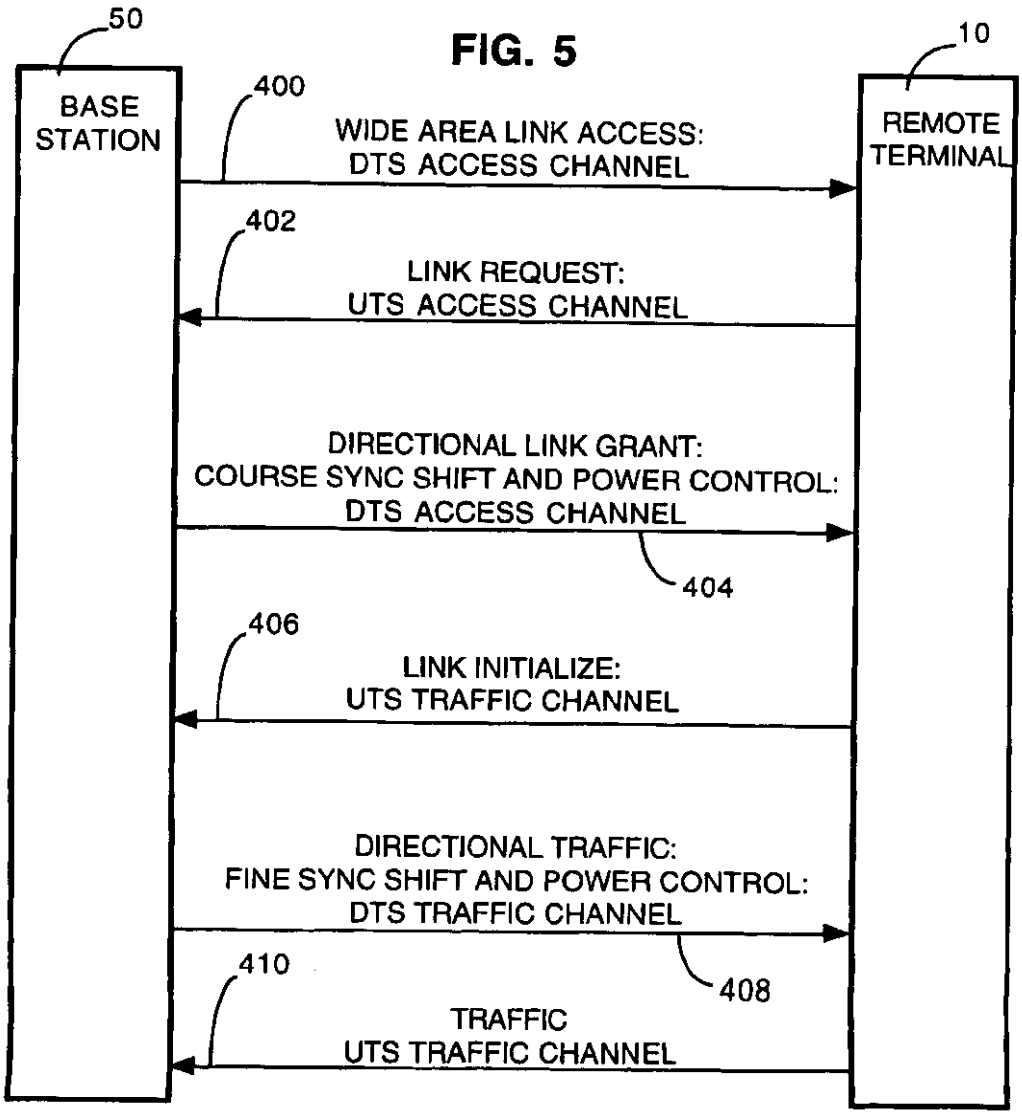

50
BASE STATION
10
REMOTE TERMINAL
400
WIDE AREA LINK ACCESS:
DTS ACCESS CHANNEL
402
LINK REQUEST:
UTS ACCESS CHANNEL
DIRECTIONAL LINK GRANT:
COURSE SYNC SHIFT AND POWER CONTROL:
DTS ACCESS CHANNEL
404
406
LINK INITIALIZE:
UTS TRAFFIC CHANNEL
DIRECTIONAL TRAFFIC:
FINE SYNC SHIFT AND POWER CONTROL:
DTS TRAFFIC CHANNEL
408
410
TRAFFIC
UTS TRAFFIC CHANNEL

FIG. 5

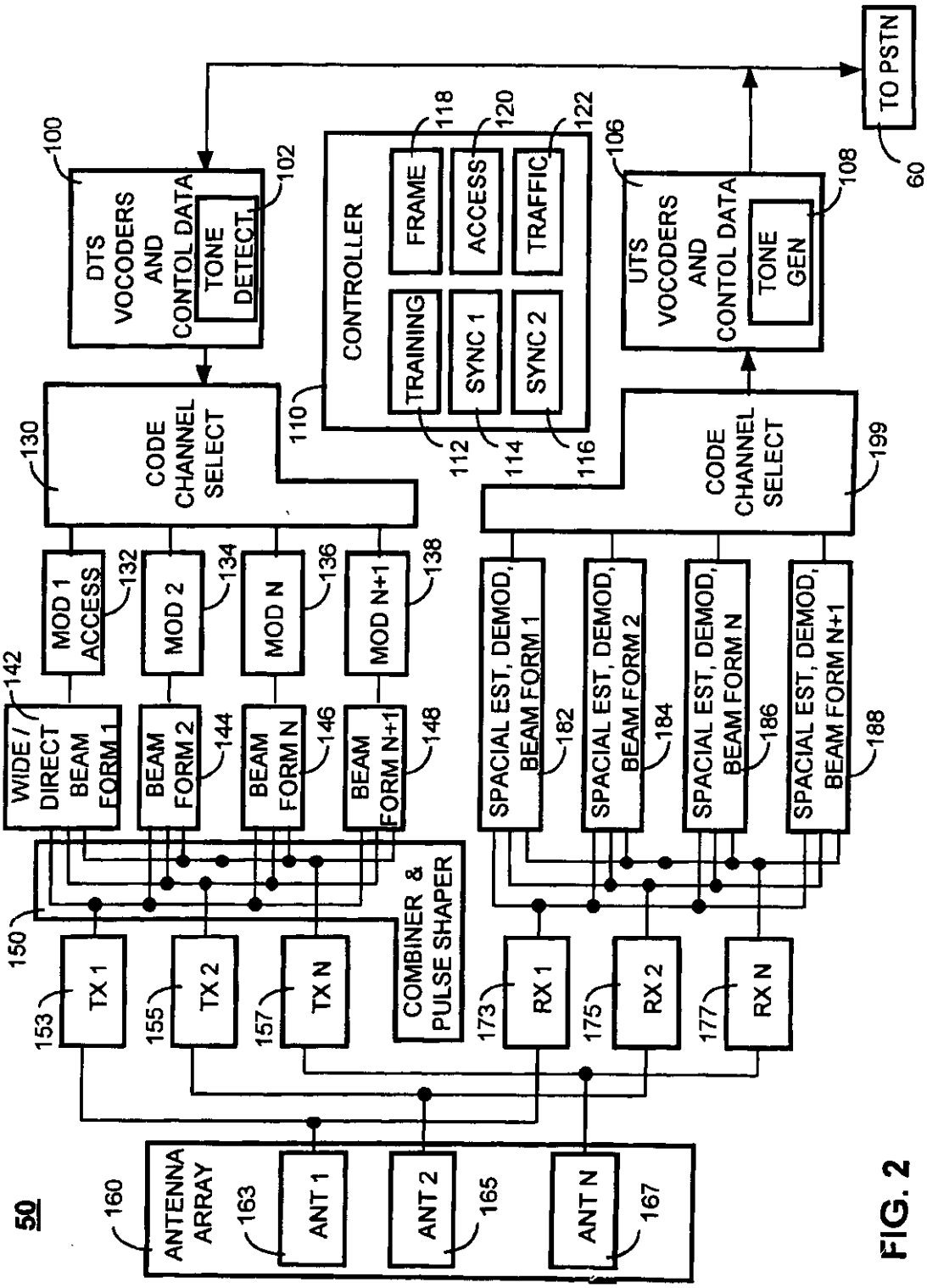

50
ANTENNA ARRAY
160
ANT 1
163
ANT 2
165
ANT N
167
TX 1
153
TX 2
155
TX N
157
COMBINER & PULSE SHAPER
150
RX 1
173
RX 2
175
RX N
177
WIDE / DIRECT BEAM FORM 1
142
BEAM FORM 2
144
BEAM FORM N
146
BEAM FORM N+1
148
MOD 1 ACCESS
132
MOD 2
134
MOD N
136
MOD N+1
138
CODE CHANNEL SELECT
130
DTS VOCODERS AND CONTOL DATA
100
TONE DETECT
102
CONTROLLER
110
TRAINING
112
SYNC 1
114
SYNC 2
116
FRAME
118
ACCESS
120
TRAFFIC
122
CODE CHANNEL SELECT
199
SPACIAL EST, DEMOD, BEAM FORM 1
182
SPACIAL EST, DEMOD, BEAM FORM 2
184
SPACIAL EST, DEMOD, BEAM FORM N
186
SPACIAL EST, DEMOD, BEAM FORM N+1
188
UTS VOCODERS AND CONTOL DATA
106
TONE GEN
108
TO PSTN
60

FIG. 2

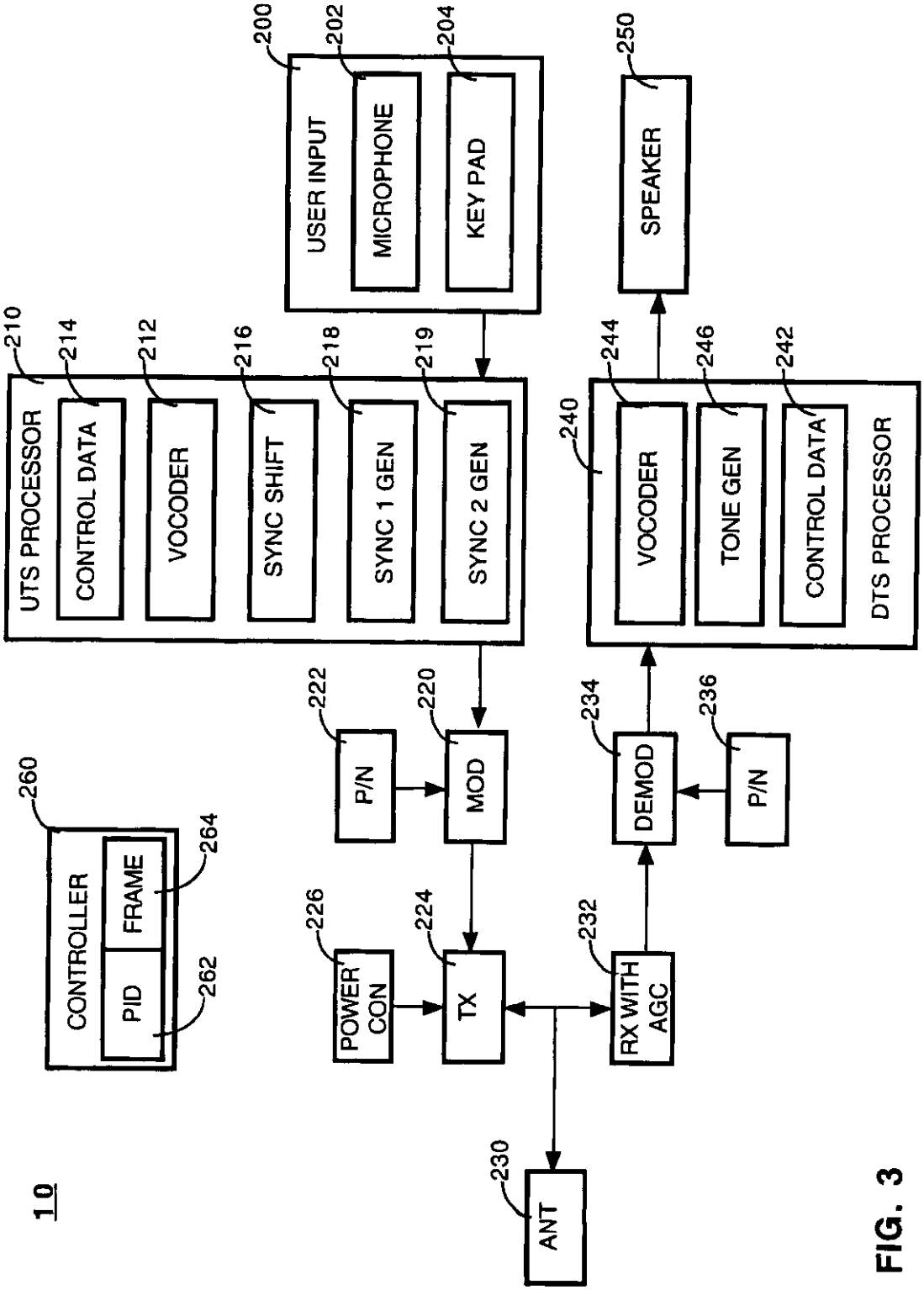

10
200
USER INPUT
202
MICROPHONE
204
KEY PAD
250
SPEAKER
210
UTS PROCESSOR
214
CONTROL DATA
212
VOCODER
216
SYNC SHIFT
218
SYNC 1 GEN
219
SYNC 2 GEN
240
DTS PROCESSOR
244
VOCODER
246
TONE GEN
242
CONTROL DATA
222
P/N
220
MOD
234
DEMOD
236
P/N
260
CONTROLLER
264
FRAME
262
PID
226
POWER CON
224
TX
232
RX WITH AGC
230
ANT

FIG. 3

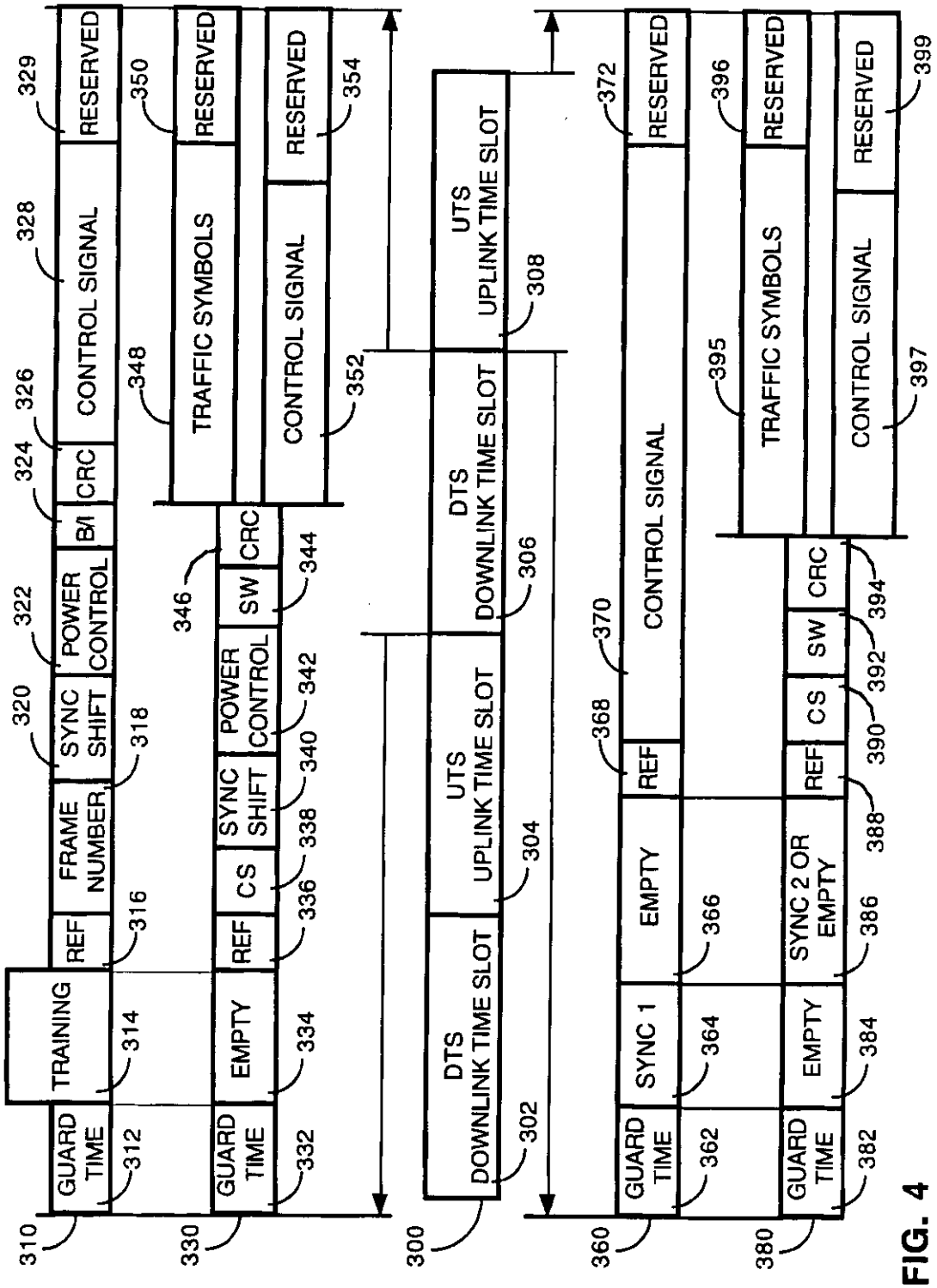

GUARD TIME
TRAINING
REF
FRAME NUMBER
SYNC SHIFT
POWER CONTROL
B/I
CRC
CONTROL SIGNAL
RESERVED
GUARD TIME
EMPTY
REF
CS
SYNC SHIFT
POWER CONTROL
SW
CRC
TRAFFIC SYMBOLS
CONTROL SIGNAL
RESERVED
DTS DOWNLINK TIME SLOT
UTS UPLINK TIME SLOT
DTS DOWNLINK TIME SLOT
UTS UPLINK TIME SLOT
GUARD TIME
SYNC 1
EMPTY
REF
CONTROL SIGNAL
RESERVED
GUARD TIME
EMPTY
SYNC 2 OR EMPTY
REF
CS
SW
CRC
TRAFFIC SYMBOLS
CONTROL SIGNAL
RESERVED
310
312
314
316
318
320
322
324
326
328
329
330
332
334
336
338
340
342
344
346
348
350
352
354
300
302
304
306
308
360
362
364
366
368
370
372
380
382
384
386
388
390
392
394
395
396
397
399

FIG. 4

FIG. 6

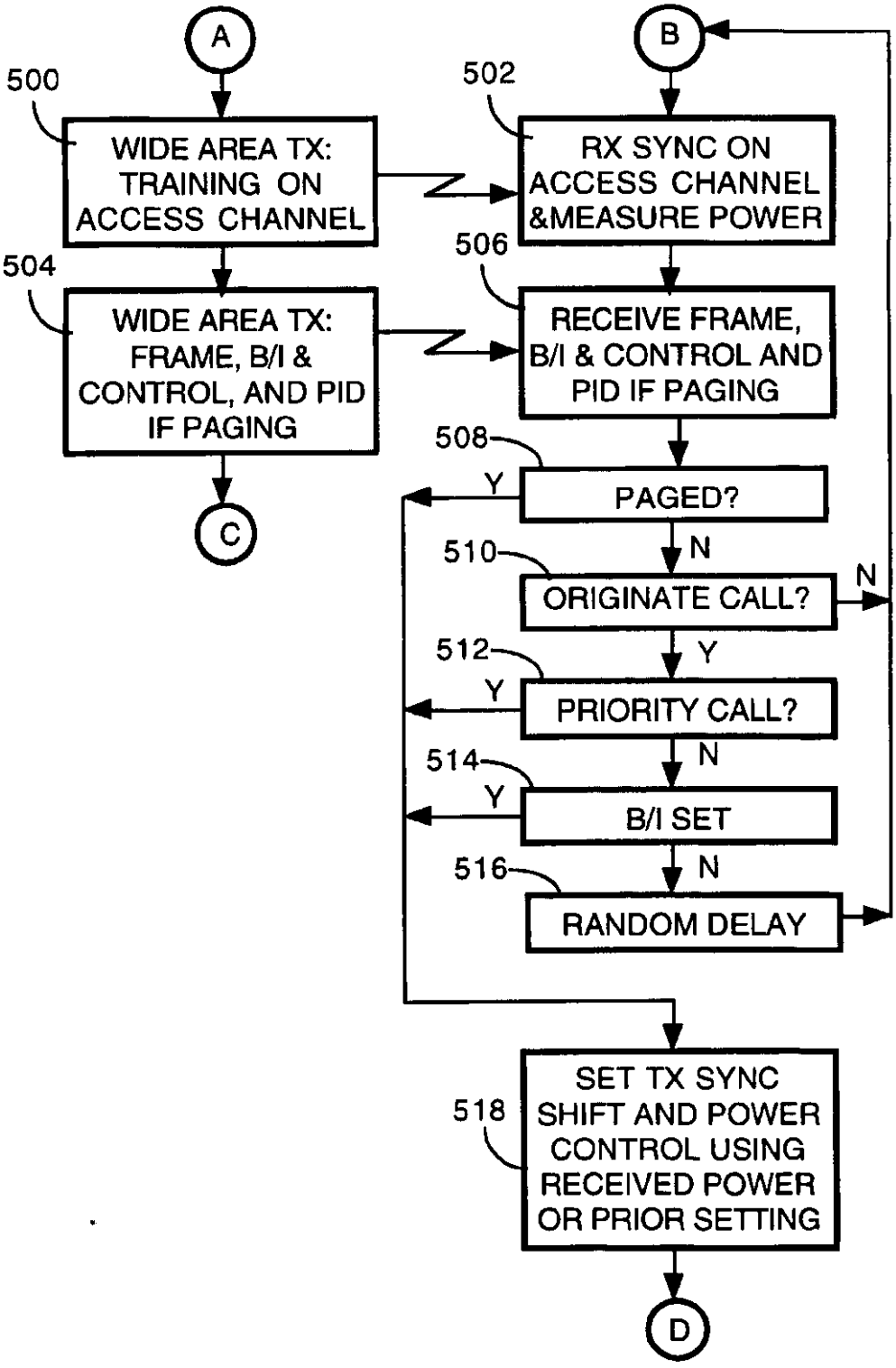

A
B
500
WIDE AREA TX: TRAINING ON ACCESS CHANNEL
502
RX SYNC ON ACCESS CHANNEL &MEASURE POWER
504
WIDE AREA TX: FRAME, B/I & CONTROL, AND PID IF PAGING
506
RECEIVE FRAME, B/I & CONTROL AND PID IF PAGING
C
508
PAGED?
Y
N
510
ORIGINATE CALL?
N
Y
512
PRIORITY CALL?
Y
N
514
B/I SET
Y
N
516
RANDOM DELAY
518
SET TX SYNC SHIFT AND POWER CONTROL USING RECEIVED POWER OR PRIOR SETTING
D

FIG. 7

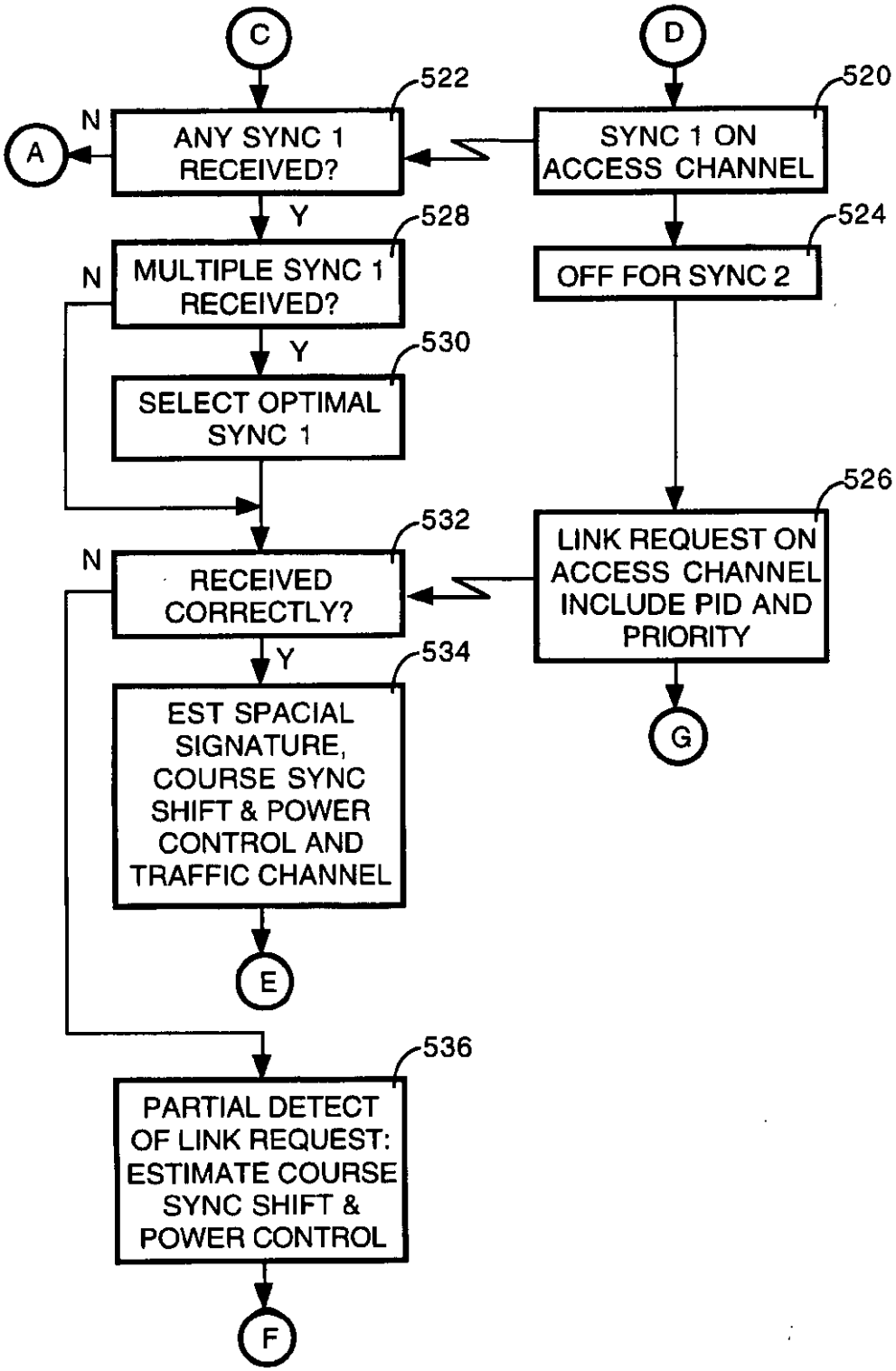

C
D
522
520
N
A
ANY SYNC 1 RECEIVED?
SYNC 1 ON ACCESS CHANNEL
Y
528
524
N
MULTIPLE SYNC 1 RECEIVED?
OFF FOR SYNC 2
Y
530
SELECT OPTIMAL SYNC 1
526
532
N
RECEIVED CORRECTLY?
LINK REQUEST ON ACCESS CHANNEL INCLUDE PID AND PRIORITY
Y
534
G
EST SPACIAL SIGNATURE, COURSE SYNC SHIFT & POWER CONTROL AND TRAFFIC CHANNEL
E
536
PARTIAL DETECT OF LINK REQUEST: ESTIMATE COURSE SYNC SHIFT & POWER CONTROL
F

FIG. 8

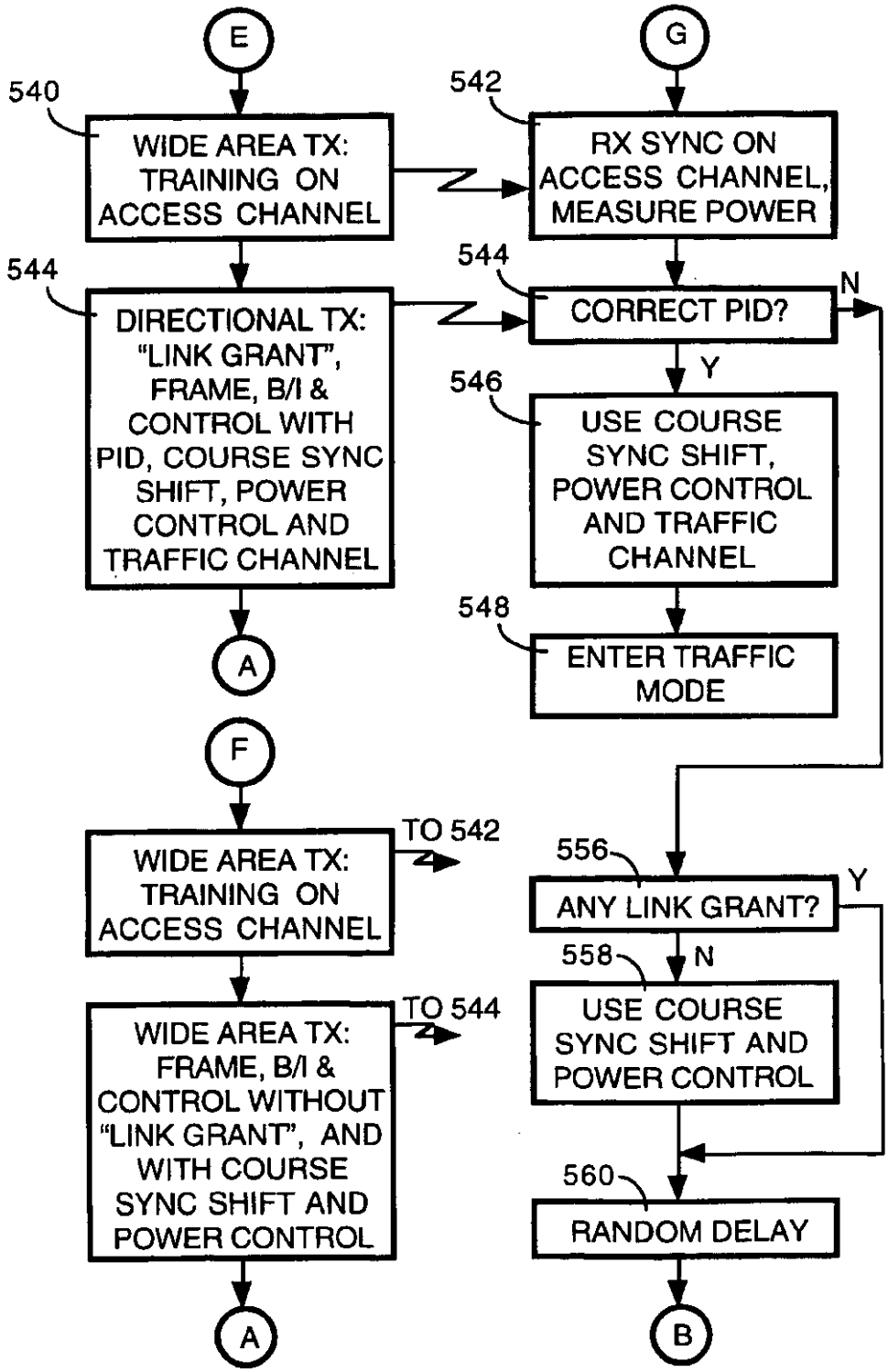
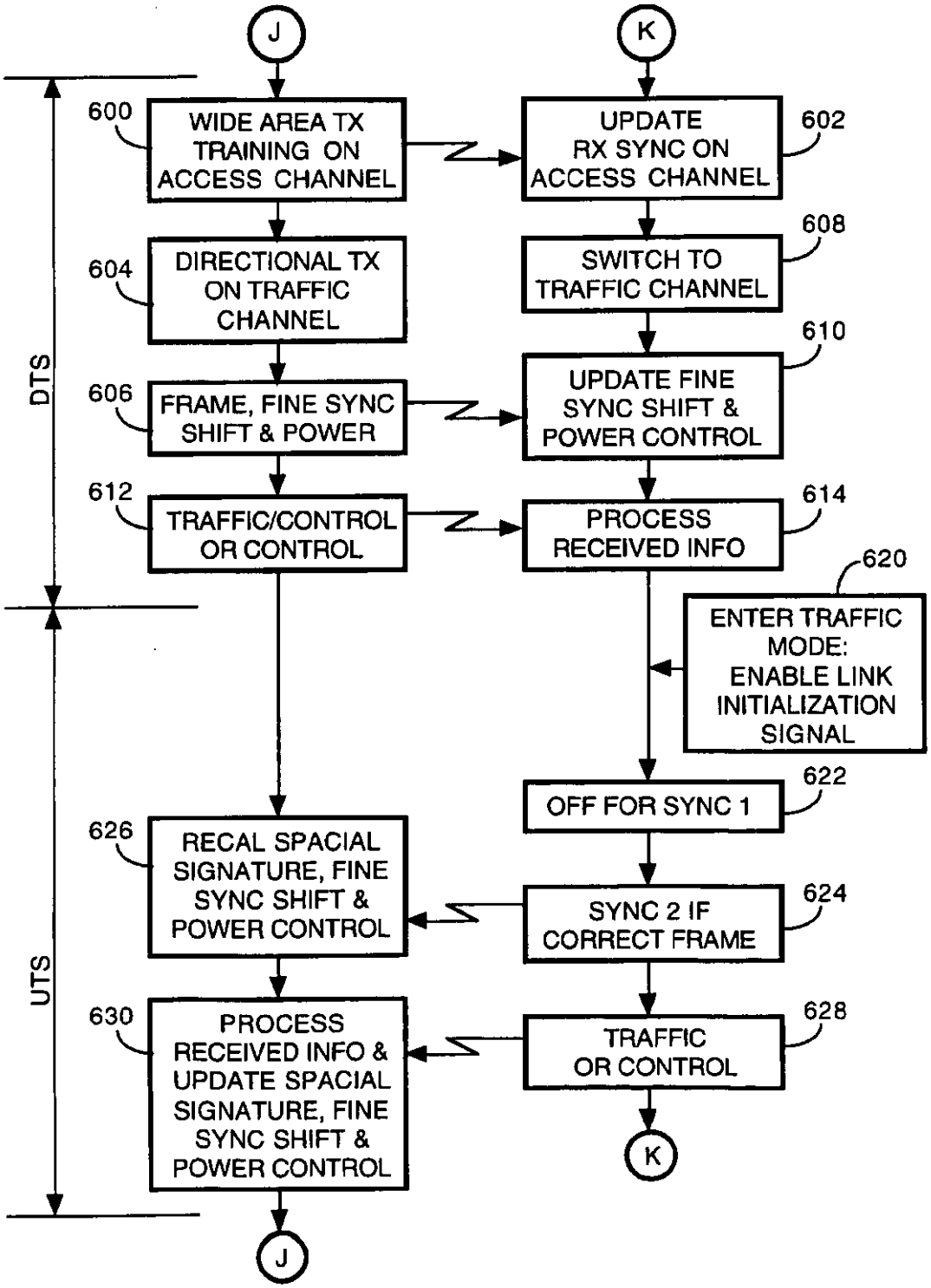

E
G
540
WIDE AREA TX: TRAINING ON ACCESS CHANNEL
542
RX SYNC ON ACCESS CHANNEL, MEASURE POWER
544
DIRECTIONAL TX: "LINK GRANT", FRAME, B/I & CONTROL WITH PID, COURSE SYNC SHIFT, POWER CONTROL AND TRAFFIC CHANNEL
544
CORRECT PID?
N
Y
546
USE COURSE SYNC SHIFT, POWER CONTROL AND TRAFFIC CHANNEL
548
ENTER TRAFFIC MODE
A
F
TO 542
WIDE AREA TX: TRAINING ON ACCESS CHANNEL
556
ANY LINK GRANT?
Y
558
N
TO 544
WIDE AREA TX: FRAME, B/I & CONTROL WITHOUT "LINK GRANT", AND WITH COURSE SYNC SHIFT AND POWER CONTROL
USE COURSE SYNC SHIFT AND POWER CONTROL
560
RANDOM DELAY
A
B

FIG. 9


J
K
600
WIDE AREA TX TRAINING ON ACCESS CHANNEL
602
UPDATE RX SYNC ON ACCESS CHANNEL
604
DIRECTIONAL TX ON TRAFFIC CHANNEL
608
SWITCH TO TRAFFIC CHANNEL
606
FRAME, FINE SYNC SHIFT & POWER
610
UPDATE FINE SYNC SHIFT & POWER CONTROL
612
TRAFFIC/CONTROL OR CONTROL
614
PROCESS RECEIVED INFO
620
ENTER TRAFFIC MODE: ENABLE LINK INITIALIZATION SIGNAL
622
OFF FOR SYNC 1
626
RECAL SPACIAL SIGNATURE, FINE SYNC SHIFT & POWER CONTROL
624
SYNC 2 IF CORRECT FRAME
630
PROCESS RECEIVED INFO & UPDATE SPACIAL SIGNATURE, FINE SYNC SHIFT & POWER CONTROL
628
TRAFFIC OR CONTROL
K
J
DTS
UTS

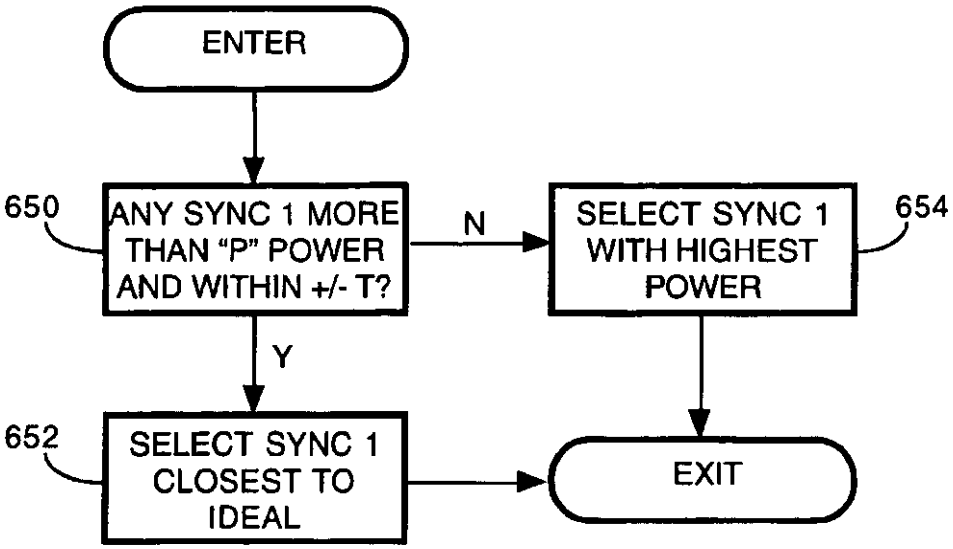

ENTER
650
ANY SYNC 1 MORE THAN "P" POWER AND WITHIN +/- T?
N
SELECT SYNC 1 WITH HIGHEST POWER
654
Y
652
SELECT SYNC 1 CLOSEST TO IDEAL
EXIT

FIG. 10

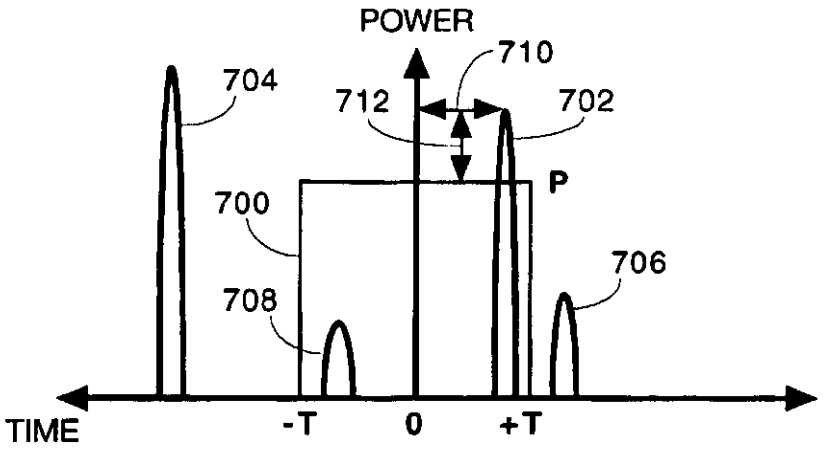

POWER
710
704
712
702
P
700
706
708
TIME
-T
0
+T

FIG. 11

FIG. 12

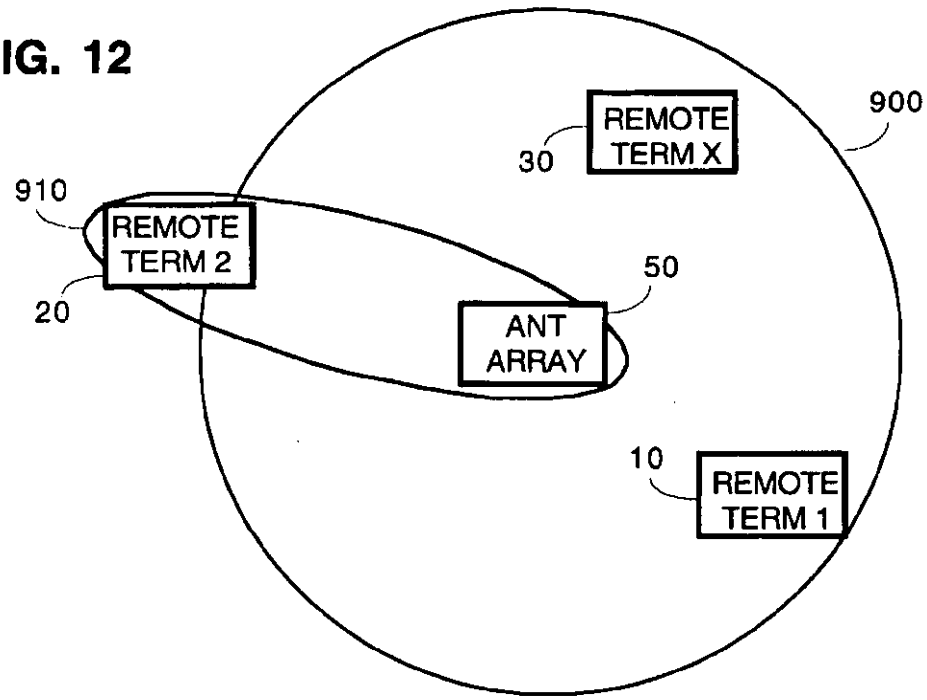
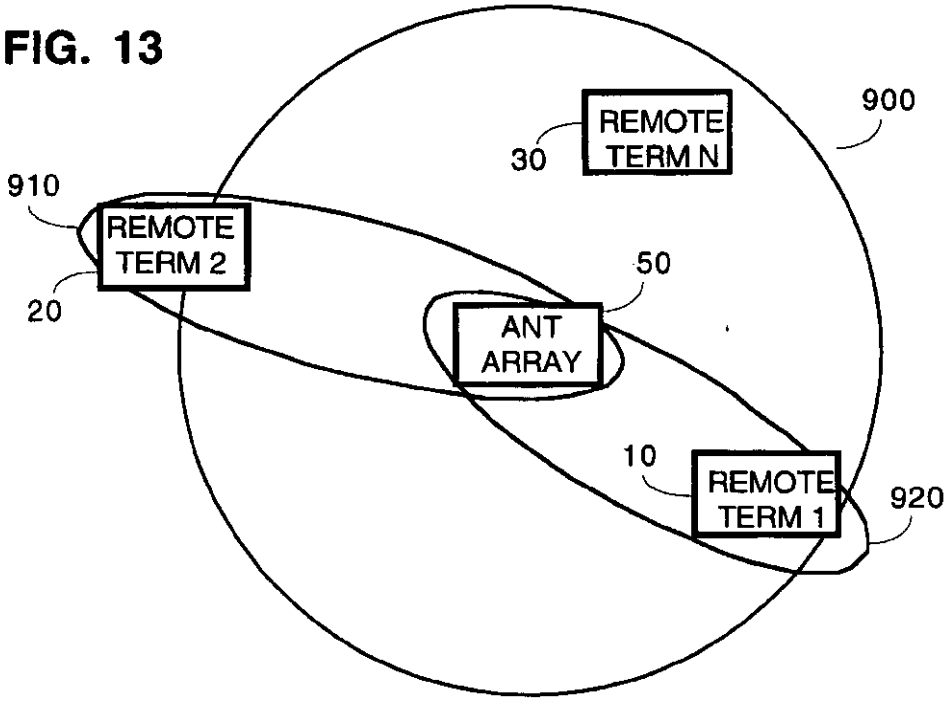

900
REMOTE TERM X
30
910
REMOTE TERM 2
20
50
ANT ARRAY
10
REMOTE TERM 1

FIG. 13


900
REMOTE TERM N
30
910
REMOTE TERM 2
20
50
ANT ARRAY
10
REMOTE TERM 1
920

SYNCHRONOUS WIRELESS ACCESS PROTOCOL METHOD AND APPARATUS

FIELD OF THE INVENTION

This invention relates to a wireless communication system. More particularly this invention relates to a synchronous code division multiple access (CDMA) communication system for wireless communication networks including wireless local loop, cellular telephony, personal communication services and wireless data networks.

BACKGROUND OF THE INVENTION

CDMA wireless communication systems allow multiple remote terminals to use multiple code channels modulated upon a common carrier frequency to communicate with a base station. CDMA systems have several advantages over alternative wireless approaches such as time division multiple access (TDMA) or frequency division multiple access (FDMA). CDMA system channel capacity can be higher and there is an improvement in multipath fading. However, systems which use frequency division duplex (FDD) to provide for 2 way wireless communication suffer from differing multipath environments on uplink and downlink communication frequencies. Smart antenna systems can improve communication between a base station and a remote terminal by providing additional robustness to CDMA "coding gain". The additional robustness is provided by directing each downlink signal toward corresponding remote terminal thereby reducing interfering signals received at one remote terminal intended for another remote terminal. The different multipath environments of the uplink and downlink deter optimization of a smart antenna based communication system. Thus, what is needed is a smart antenna CDMA communication system which provides for a common frequency for both uplink and downlink communications. Also what is needed is a communication system which enables improved spacial estimations of a remote terminal in order to improve the directional characteristics of a smart antenna.

Synchronous CDMA systems provide improved coding gain over asynchronous CDMA systems. However, synchronization signals can use significant bandwidth or require complex processing in the base station or remote terminal, thereby increasing the cost of the communication system. Thus, what is needed is a communication system which provides synchronous CDMA communication on both the uplink and downlink communication channels without adding significant cost or bandwidth to the communication system.

In a typical communication system, base station signals may be received by numerous remote terminals, while only a few remote terminals are communicating information with the base station. However, when a call is initiated, it is desirable that the link between the remote terminal and the base station be established as quickly as possible. Therefore what is needed is a CDMA communication system which provides for rapid establishment of a communication link between a remote terminal and a base station. Two remote terminals attempting to simultaneously establish a link may cause collision interference at the base station, therefore what is needed is a communication system which efficiently addresses recovery from such collisions. Furthermore, during the establishment of the communication link, large course adjustment in synchronization and power levels of the remote terminal should be provided. However, once the link is established smaller fine adjustments of synchronization and power control if used, would reduce overhead. However, the large course adjustment signals use more channel capacity than needed once a link is established and consequently waste channel capacity. Thus, what is needed is a communication system which reduces the channel capacity used to synchronize a remote terminal once a link is established.

OBJECTS OF THE INVENTION

Objects of the invention include providing for the aforementioned needs.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** shows a block diagram of a communication system operating in accordance with the present invention.

FIG. **2** shows a block diagram of a base station in accordance with the present invention.

FIG. **3** shows a block diagram of a remote terminal operating in accordance with the present invention.

FIG. **4** shows a protocol format in accordance with the present invention.

FIG. **5** shows communication between a base station and a remote terminal in establishing and maintaining a communication link in accordance with the present invention.

FIGS. **6** through **10** shows a detailed flow diagram of the operation of a base station and a remote terminal in accordance with the present invention.

FIG. **11** illustrates relative timing and power levels used for selecting one of several concurrent sync **1** signals in accordance with the present invention.

FIGS. **12** and **13** show various wide area and directional radiation patterns of a base station operation in accordance with the present invention.

DESCRIPTION OF A PREFERRED EMBODIMENT

FIG. **1** shows a block diagram of a communication system operating in accordance with the present invention. A plurality of remote terminals **10**, **20** and **30**, are wirelessly coupled to a base station **50** which interfaces to a public switched telephone network (PSTN) **60** and a destination **70**. A base station controller (not shown) may be interposed between the PSTN **60** and a plurality of base stations, including base station **50**, to coordinate the operation of the plurality of base stations. In a typical application a user at the destination engages in a full duplex voice communication with a user of a remote terminal. In alternate embodiments, either destination or remote can communicate digital information, such as FAX or modem information between computers. Also, the PSTN itself may be a destination for some of the information, such as control signals like dual tone multiple frequency (DTMF) signals, generated by a remote terminal.

The wireless interface between the base station and a remote terminal uses a synchronous code division multiple access protocol (S-CDMA). In a S-CDMA system a plurality of concurrent code channels are modulated upon a common carrier frequency. The communication system of the present invention uses time division duplex (TDD), the carrier frequency is divided into time slots for downlink communications (base station to remote terminals) via downlink time slots (DTS) and for uplink communications (remote terminals to base stations) via uplink time slots (UTS). The communication system of the present invention

takes advantage of the identical RF propagation paths of the downlink and the uplink due to TDD to implement an improved smart antenna beam forming base station for generating directional radiation patterns from an antenna array included in the base station. Although the preferred embodiment is described with respect to a TDD CDMA system, the invention is not limited thereto. Inventions herein may also be applied to frequency division duplex (FDD) and/or time division multiple access (TDMA) and/or other systems.

FIG. **2** shows a block diagram of base station **50** in accordance with the present invention. Information is received for use in a DTS frame by DTS vocoders and control data generator **100** from a destination through the PSTN, **60**. Included therein are at least one vocoder for each code channel supported by the base station for digitizing voice signals. Vocoders are well known in the art and a 8 Kbps fixed rate vocoder ITU Rec. G.729 may be preferably used. Preferably all vocoders used in this invention for both uplink and downlink communication are of the same type. In alternate embodiments, variable rate or alternate methods of digitizing voice and presenting a time variable representation of the signal received from the PSTN may be used. Also included is a control data generator for generating and transmitting control data in both a DTS access channel and a DTS traffic channel as described in more detail hereinafter. Also included is a tone detector **102** for detecting DTMF or other control tones received via the PSTN, and creating a signal indicative of the frequency thereof. The tone is then replaced with a digital control signal indicative of the frequency components of the tone. By this method, a better representation of the control tone or tones may be regenerated at a remote terminal without introduction of distortion by a vocoder. In alternate embodiments other signal detectors may be substituted for detector **102** for detecting the presence of FAX or computer modem signals and regenerating digital representations thereof.

Information is received and demodulated from remote terminals **10–30** in a UTS frame and presented to UTS vocoders and control data generator **106**. The converted information is then made available to the destination through the PSTN **60**. Included therein are at least one vocoder for each code channel supported by the base station for digitizing voice signals. Also included is a control data interpreter for responding to control data received in both a UTS access channel and a UTS traffic channels as described in more detail hereinafter. Also included is a tone generator **108** for generating DTMF or other control signals originating at remote terminals, and creating a signal indicative of the frequency thereof for the PSTN. By this method, a better representation of the control tone or tones may be regenerated and sent to or through the PSTN without introduction of any vocoder distortion.

Controller **110** controls and coordinates the operation of the elements of base station **50**, and includes training signal generator **112**, sync 1 processor **114**, sync 2 processor **116**, frame number generator **118**, UTS and DTS access channel processors **120**, and UTS and DTS traffic channel processors **122**. The operation of these elements will be described in more detail hereinafter.

Code channel selector **130** directs information from DTS vocoders and control data **100** to the at least N+1 modulators **132–138** for use on the at least N+1 code channels of the base station. The access channel is shown directed to modulator **1**, **132**. The traffic channels are directed to remaining modulators **134–138**. Modulators **132–138** modulate each channel with a unique orthogonal spreading code in a manner known to those familiar with CDMA art. The output of each modulator is coupled to a corresponding beam former **142–148** which modulates the power and phase of each channel for each element of antenna array **160** and on the code channel on the common carrier frequency. The array of beam formers **142–148** generates a unique radiation pattern for each code channel for directing signals toward each corresponding remote terminal. This has the advantage of reducing the interference of DTS frames of one remote terminal interfering with DTS frames of another remote terminal. This reduction of interference significantly improves the robustness of the communication system and the quality of the signal received by each remote terminal. The outputs of each beam former **142–148** are concurrently combined and pulse shaped to shape the transmitted signal spectrum by combiner and pulse shaper **150**. Combiner and pulse shaper **150** combines and shapes outputs of beam formers **142–148** for antenna **1**, **163** and couples them to transmit amplifier **1**, **153**. Similarly, combiner and pulse shaper **150** combines and shapes outputs of beam formers **142–148** for antenna **2**, **165** and couples them to transmit amplifier **2**, **155**. Similarly, combiner and pulse shaper **150** combines and shapes outputs of beam formers **142–148** for antenna N, **167** and couples them to transmit amplifier N, **157**. Note that bream former **142**, for the access channel, transmits both a wide area radiation pattern and a directional radiation pattern, the purpose of which will be described herein.

N receivers **173–177**, coupled to corresponding N antenna **163–167**, receive and demodulate information from remote terminals in UTS frames. There are at least N+1 spacial estimation, demodulation and beamformers **182–188** for processing CDMA code channels received on each of the N antennas of the antenna array **160**. Demodulation includes despreading each received code channel from each antenna using a predetermined orthogonal P/N code. Spacial estimation, demodulation and beamformer **1**, **182**, is used for receiving the UTS access channel and spacial estimation, demodulation and beamformers **2** through N+1 are used for receiving UTS traffic channels. Spacial estimation, demodulation and beamformers **182–188** analyze the power and phase of each code channel received on each antenna during a UTS frame. The processed information is then made available to corresponding beam formers **142–148** for generating directional radiation patterns in DTS frames. Alternate methods of beam forming are described in detail in co-pending U.S. patent application entitled S-CDMA Smart Antenna System, Ser. No. 08/768,100 filed Dec. 6, 1996 and assigned to the assignee of the present invention which is hereby incorporated by reference. The output of each spacial estimation, demodulation and beamformer is coupled to UTS vocoders and control data **106** via code channel selector **199** for communication with the PSTN **60**.

In a preferred embodiment, N=eight, thus there are eight: transmitters **153–157**; antennas **163–167** of antenna array **160**; and receivers **173–174**. Further, the at least N+1=thirty two, thus there are thirty two modulators **132–138**, beam formers **142–148**, spacial estimation, demodulation and beamformers **182–188** allowing for thirty two CDMA code channels comprising one access channel and thirty one traffic channels.

In the preferred embodiment, the bulk of the process in the base station are implemented by software operating on an array of digital signal processors (DSPs), including devices **100** through **150** and **182** through **199**.

FIG. **3** shows a block diagram of a remote terminal operating in accordance with the present invention. A user

input means **200** allows a user of the remote terminal **10** to input both voice signals via microphone **202**, and dial phone numbers via key pad **204**. User input means may also receive signals from data devices such a FAX or computer modem signals. User input means **200** is coupled to UTS processor **210** for causing transmission of a UTS frame by the remote terminal. Microphone **202** is coupled to vocoder **212** for generating a digital representation of the time variable voice signals. Key pad **204** is coupled to control data means **214** for generating a digital representation of the frequency domain control tones corresponding to the DTMF tones resulting from user activating key pad **204**. FAX and computer modem signals may also be received and processed by control data means **214**. Additionally, sync shift **216** data is processed, and sync 1 and sync 2 are generated, **218** and **219**. UTS frames are then modulated by modulator **220**, which spreads the UTS frame on a code channel in accordance with P/N code **222**. Modulator **220** modulates the code channel on the common carrier frequency used concurrently by other remote terminals UTS frames. Transmitter **224** then amplifies the output of the modulator at a power level set by power control **226**. The output of transmitter **224** is then coupled to antenna **230** for wireless communication with base station **50**.

DTS frames are received by antenna **230** and receiver **232** which may include gain control means for automatically regulating the gain of the receiver. Demodulator **234** then despreads the received signal to recover a desired code channel in accordance with P/N **236**. The power of the received signal is also determined by receiver **232** and demodulator **234**. The demodulated DTS frame is then processed by DTS processor **240** which processes control data **242** from the base station, and traffic information is presented to vocoder **244** which generates an audio output via speaker **250** generates which may be recognized by the user in voice communication with another at the desired destination. Control data means **242** may also provide a FAX or computer modem signals. DTS processor also has a tone generator **246** for generating tones on speaker **250** corresponding to either key pad **204** being pressed or control data received in a DTS frame. Remote terminal **10** also includes a controller **260** having a personal identification (PID) uniquely assigned to the remote terminal, and a frame number assigned to the remote terminal in a signal included in a DTS frame. Preferably, the UTS processor **210**, modulator **220**, P/N **222**, power control **226**, demodulator **234**, P/N **236**, DTS processor **250** and controller **260** are substantially implemented by software operating with a DSP within the remote terminal.

FIG. **4** shows a protocol format in accordance with the present invention. Line **300** shows four frames, **302–308**, divided into time slots. Downlink time slots (DTS) frames **302** and **306** are for communication from the base station to the remote terminals, and uplink time slots (UTS) frames **304** and **308** are for communication from the remote terminals to the base station. Within the frames of line **300** are the concurrent code channels modulated upon a common carrier frequency which enable the TDD CDMA communication system.

Preferably each UTS and DTS frame is substantially 5 mS in duration and consists of sixty four digital symbols modulated using differential quadrature phase shift keying (DQPSK), at two bits per symbol. Alternately, other frame durations and symbol modulations such as FSK or QAM may be used. Each symbol is spread by a P/N chip sequence, preferably the chip sequence used on each code channel is a 32 bit orthogonal code.

Line **310** shows the protocol format of the DTS access channel of frame **306**. The access channel **310** is modulated using a predetermined spreading code or P/N sequence. Guard time field **312** allows for RF propagation delays between the base station and the remote terminal and is preferably five symbols in duration. The base station is not transmitting during the guard time field. Training signal field **314** is provided to allow remote terminals to synchronize to the training signal in the UTS frame. The training signal is preferably 15 dB higher in RF power than the rest of the symbols of the access channel and is four symbols in duration. Reference field **316** is one symbol having a predetermined value and may be used to facilitate DQPSK demodulation, the predetermined value is preferably "11". Frame number field **318** is a signal identifying each frame. Preferably, there are thirty two frames, the frame number ranging from zero to thirty one, and the frame number field is three symbols in duration. The sync shift field **320** provides timing information for use by a remote terminal in transmission of a UTS frame. Sync shift information enables substantially synchronized arrival of all UTS frames at the base station from all remote terminals in communication with the base station, even though the the remote terminals are at varying distances from the base station thereby having variable propagation delays. Preferably the sync shift field **320** is five and one half symbols in duration allowing for +/− thousand and twenty four steps of adjustment at one sixteenth of a chip period per step. Power control field **322** provides for course power adjustment of the transmitter of a remote terminal during link acquisition. This allows the base station to regulate the power of the UTS frames received from each of the remote terminals. Preferably power control field **322** is three symbols allowing an adjustment of +/− thirty two steps at one dB per step. The B/I field **324**, busy/idle, indicates the availability of traffic code channels for remote terminals attempting to initiate communication with the base station. It is preferably one half symbol in duration. A cyclic redundancy code (CRC) field **326** assures validity of prior fields **318**, **320**, **322** and **324** and is preferably three symbols in length. Control signal field **328** is used to communicate information to remote terminals. The information includes a link access paging signal having information corresponding to a unique personal identification (PID) assigned to a remote terminal for communicating a call originating from the PSTN and a corresponding link grant signal. Other information includes base station identification, channels used, information about adjacent base stations, as well as information which may be useful to users of the remote terminals such as time of day and weather information. Preferably the control signal field **328** is thirty six symbols in duration. Finally, reserved field **329** is left for future definition.

Line **330** shows the protocol format of the DTS traffic channel of frame **306**. Preferably there are up to thirty one concurrent orthogonally modulated traffic channels plus the concurrent access channel **310** having a common carrier frequency within a DTS frame. Guard time **332** corresponds to guard time **312** of the access channel. Empty slot **334** corresponds to the occurrence of training signal **314**. The traffic channels **330** are not modulated during empty field **334** while the training signal **314** is being modulated upon the access channel. This has the advantage of allowing remote terminals to synchronize to the training signal on the DTS access channel prior to receiving information on their DTS traffic channel. Reference signal **336** is one symbol having a predetermined value and may be used to facilitate DQPSK demodulation. Preferably the value of reference

signal **336** is predetermined and preferably a "11". Control signal (CS) field **338** contains a portion of a complete control signal and is preferably four symbols in duration. Sync shift field **340** is a reduced version of sync shift field **320** of the access channel. The access channel allows for course adjustment of the synchronization of a remote terminal while the traffic channel allows for fine adjustment of synchronization. The fine adjustment field **340** has the advantage of allowing for more information to be used in other fields and reduces the amount of sync adjustment that may be done when a remote terminal is receiving a traffic channel. Preferably synch shift **340** is one symbol in duration allowing for: no change in synchronization, or a +1, −1 or −2 leading step wherein a step is one sixteenth of a chip. Power control field **342** is a reduced version of power control field **322** of the access channel. Preferably power control **342** is two symbols in duration allowing for: no change in synchronization, or up to +7 steps, up to −8 steps in transmit power adjustment wherein a step is one dB. The reduce version has the advantage of allowing for more information to be used in other fields of the traffic channel and reduces the amount of adjustment that may be done when a remote terminal is receiving a traffic channel. Thus, the access channel allows for a one time course adjustment of the sync shift and transmit power of a remote terminal while the traffic channel has the advantages of both allowing for more frequent, substantially once every ten milliseconds, fine adjustments of synchronization and transmit power, and being smaller in size to improve the throughput of information to the remote terminal. Although the step size of the course sync shift **320** and power control **322** fields are shown equivalent to the step size of the fine sync shift **340** and power control fields **342**, alternate embodiments may reduce the step size of the fine sync shift and power control fields relative to the course adjustment to further enhance the accuracy of the system.

The SW field **344** indicates the structure of the information following CRC field **346**, which may be either traffic signals produced by a vocoder in the base station, or any of several types of control signals. Preferably the SW field is one symbol indicating either traffic symbols, or whether DTMF or other control information such as call termination or cell handoff information is included in the control signal. Cyclic redundancy code (CRC) field **346** assures validity of prior fields **338–344** and is preferably one symbol. When the SW field **344** indicates that traffic symbols follow CRC **346**, traffic symbols field **348** follows and includes information used by a vocoder in a remote terminal to produce audio signals. Preferably the traffic symbols field **348** is forty three symbols in length. Reserved field **350** is for future definition. When the SW field **344** indicates that control signals follow CRC **346**, control signal field **352** follows and includes the type of information previously described. Preferably the control signal field **352** is thirty six symbols in length. Reserved field **354** preferably is for future definition. Note that when SW indicates traffic symbols **348** are transmitted, information that may have been sent in control signal **352** may alternately be distributed in nine occurrences of the CS field **338** in nine DTS frames.

Thus, lines **310** and **330** of FIG. **4** show a data protocol format in a wireless communication system of FIG. 1, the data protocol format for communicating from a base station **50** of FIG. **2** to a plurality of remote terminals **10, 20** and **30** on a plurality of concurrent code channels **310** and **330** modulated upon a common carrier frequency. The data protocol format comprises an access channel **310** modulated upon a first of the plurality of code channels. The access channel includes a synchronization portion **314** and a control portion **316–329** following said synchronization portion. The traffic channel **330** modulated upon a second of the plurality of code channels includes a null portion **334** occurring concurrently with said synchronization portion **314** and a traffic portion **336–350** or **336–354** occurring concurrently with said control portion.

Line **360** shows the protocol format of the UTS access channel of frame **308**. In a UTS frame remote terminals transmit signals received by the base station. A predetermined spreading code is used when transmitting on the UTS access channel. Guard time **362** has a similar function as described with respect to guard time **312**. Sync **1** field **364** is for use by remote terminals attempting to establish communication with the base station, and is a predetermined pattern preferably three symbols in length. After sync **1, 364**, is an empty slot, **366**, where the transmitter of a remote terminal attempting to access the base station is shut off. Thereafter, a reference signal **368** consists of one symbol having a predetermined value and may be used to facilitate DQPSK demodulation, the predetermined value may preferably be a "11". Control signal **370** includes information from the remote terminal attempting to access the base station. Such information includes a link request signal, the PID of the remote terminal and the priority of a call initiated at the remote terminal. An example of priority is whether the call is a high priority "911" or a normal priority call. Preferably the control signal field **370** is thirty six symbols in duration. Reserved field **372** is for future definition.

Line **380** shows the protocol format of the UTS traffic channel of frame **308**. Preferably there are up to thirty one concurrent orthogonally modulated traffic channels transmitted by up to thirty one remote terminals plus the concurrent access channel **360** having a common carrier frequency within a UTS frame received by the base station. Guard time **382** corresponds in functionality to guard time **312** of the DTS access channel. Empty slot **384** corresponds to the occurrence of the sync 1 field **364**. The traffic channels **380** are not modulated during empty field **384** while the sync **1** signals **364** may be transmitted upon the access channel. This has the advantage of allowing the base station to synchronize to the sync **1** signals of a remote terminal which has not yet received sync shift and power control signals from the base station. The absence of concurrent traffic channels during the sync **1** field enables the the base station to more accurately perform power control, sync shift and spacial estimations on the remote terminal. Furthermore, a remote terminal may attempt to establish a link on any UTS frame allowing for quicker link establishment between the base station an the remote terminal. Thereafter, a sync **2** field **386** enables a selected remote terminal to transmit a synchronization signal. Preferably a remote terminal transmitting in this field is selected by frame number, more particularly by an index that is indicative of both the frame number and the spreading code to use for communicating on a code channel assigned by the base station. Thus, only one remote terminal is transmitting during the sync **2** field even though up to thirty one remote terminals may be communicating on the thirty one code channels for UTS traffic. In alternate embodiments multiple remote terminals may concurrently transmit sync **2** signals to a common base station in a single UTS frame. For example, sixty four code channels could be incorporated into a thirty two frame protocol if only the five most significant bits of the index of the sixty four code channels were used to select a frame for transmitting in a sync **2** field. In this example, remote terminals having a code index of two and thirty four would transmit sync **2** in frame two, while remote terminals with code indexes of zero, one,

three through thirty one, and thirty three through sixty three would not transmit sync **2** in frame two. Reference signal **388** is one symbol having a predetermined value and may be used to facilitate DQPSK demodulation, preferably the predetermined value is "11". Control signal (CS) field **390** contains portion of a complete control signal and is preferably two symbols in duration. Similar to the SW field **344** of the DTS frame, the SW field **392** of the UTS frame indicates whether information following the CRC **394** contains traffic symbols **395** or a control signal **397**, which are similar in function and preferred size to the corresponding DTS traffic signals **348** and control signal **352**. In the event traffic signals **395** are present on a UTS traffic channel, then CRC is calculated based upon fields **392** and **395**. Reserved fields **396** and **399** are reserved for future definition.

Lines **360** and **380** show a data protocol format in the wireless communication system of FIG. **1**, the data protocol format for communicating from a plurality of remote terminals **10, 20** and **30** to a base station **50** on a plurality of concurrent code channels **360** and **380** modulated upon a common carrier frequency. The data protocol format comprises an access channel **360** modulated upon a first of the plurality of code channels including a first synchronization portion, sync **1** field **364**, a first null portion following said first synchronization portion, empty field **366**, and a control portion following said first null portion, field **370**. Furthermore, a traffic channel **380** is modulated upon a second of the plurality of code channels. Traffic channel **380** includes a second null portion, empty field **384**, occurring concurrently with said first synchronization portion, sync **1** field **364**. Traffic channel **380** also includes a second synchronization portion, sync **2** field **386**, occurring concurrently with said first null portion, empty field **366**. Traffic channel **380** also includes a traffic portion, field **395** or field **397**, occurring concurrently with the control portion, control signal field **370**.

FIG. **4** shows providing a course synchronization signal **320** and **322** for a remote terminal on a first code channel and providing a fine synchronization signal **340** and **342** for the remote terminal on a second code channel.

FIGS. **3** and **4** show a communication system has a plurality of frames **304** and **308** for communication from a plurality of remote terminals to a base station on a common carrier having a plurality of concurrent code channels. Each frame having a first portion corresponding to sync **1 364** and empty **384**, a second portion corresponding to sync **2 386** and empty **366**, and a third portion including signals **370, 395** and **397**. The remote terminal comprises: a controller **260** for controlling operation of the remote terminal in a access mode while receiving access channel **360** and a traffic mode while receiving traffic channel **380**; a first synchronization generator **218** responsive to said controller for generating a first synchronization signal; a second synchronization generator **219** responsive to said controller for generating a second synchronization signal; a data modulator **220** responsive to said controller for generating modulated information signals; and a transmitter **224** coupled to said first synchronization generator, said second synchronization generator and said data modulator for generating a radio frequency modulated transmit signal indicative of the first and second synchronization signals and the information signals in response to said controller, wherein, in the access mode, said controller enables said transmitter and said first synchronization generator in the first portion, disables the transmitter in the second portion, and enables said data modulator and said transmitter in the third portion during a first frame, and in the traffic mode, said controller disables said transmitter in the first time slot, enables said transmitter and said second synchronization generator in the second portion, and enables said transmitter and said data modulator in the third portion during a second frame subsequent to the first frame.

FIG. **5** shows communication between a base station and a remote terminal for establishing and maintaining a communication link. When a call originates through the base station **50**, typically from a destination coupled to the PSTN, the base station transmits a link access signal, or sends a page to the intended remote terminal **10** on the DTS access channel at link **400**. The base station has beam forming capabilities but may not have information on the current location or optimal directional beam for communicating with remote terminal **10**. Consequently the link access signal is transmitted in a wide area or substantially omnidirectional mode. The remote terminal responds at **402** with a link request signal on the UTS access channel. Alternatively, if a call originates at the remote terminal, the process starts at the link request signal **402**. The remote terminal uses the power of the training signal to estimate an initial sync shift and power control level to transmit the link request signal at **402**. The base station uses the link request to perform a spacial estimation of the direction of the remote terminal and then transmits a link grant signal on the DTS access channel at **404**. The link grant signal directionality is the result of beam forming done by the base station in response to the spacial estimation. Alternatively, the link grant signal may be transmitted omnidirectionally. Additionally, using the received link request signal, the bases station determines an appropriate course sync shift and power control signal. This information is also communicated to the remote terminal in the link grant signal along with an index of an available traffic channel. Thereafter, the remote terminal responds on the available traffic channel in a UTS frame with a link initialize signal at **406**. Thereafter traffic information is communicated between the base station and remote terminal in DTS and UTS frames for the duration of the communication at **408** and **410**. Additionally, the base station monitors the UTS transmissions from the remote terminal to adjust the directionality of the DTS code channel as well as the sync shift and power control signals for the remote terminal.

FIGS. **6** through **10** show a detailed flow diagram of the operation of a base station and a remote terminal in accordance with the present invention. Beginning at FIG. **6**, which indicates a process in a UTS frame, in step **500** the base station transmits the training signal on the access channel in a wide area radiation pattern intended such that all remote terminals in an area covered by the base station may receive the training signal. The training signal is received by the remote terminal at step **502**, wherein the remote terminal measures the received power of the training signal as well as using the training signal for synchronization to the rest of the information on the access channel. Then at step **504** the remainder of the access channel for the DTS frame is transmitted in the wide area mode. The remote terminal receives the rest of the access channel information at step **506**. A page is checked for at step **508** by determining if a PID matching the PID of the remote terminal is received. The page could also be pending from a prior attempt to establish a link, where the link was not granted. If not paged, step **510** checks to see if a call is being originated at the remote terminal, typically by a user of the remote terminal. The call could also be pending from a prior attempt to establish a link, where the link was not granted. If not the remote terminal returns to step **502** for the next DTS frame.

If a call is originated at step **510**, step **512** checks if the originating call is a high priority call, such as a "911" call. If not, step **514** checks if the B/I field indicates available code channels. If not, step **516** invokes a random delay of frames before attempting to establish a communication link. If paged at step **508**, or a call is originated at steps **512** or **514**, then step **518** sets the transmit sync shift and power control using the received power of step **502**. Since the attenuation of the received power may be substantially proportional to the distance of the remote terminal from the base station, the appropriate sync shift may be determined such that information transmitted by the remote terminal on the access channel may arrive at the base station at substantially a correct power level and timing so that the base station may also maintain CDMA communication with other remote terminals on traffic channels. Alternately a prior setting of sync shift and power control received from the base station may be used. The prior setting is advantageous if the remote terminal has had a substantially constant location or the prior setting was recently received.

The processes of the remote terminal proceed through connector "D" of FIG. **6** to connector "D" of FIG. **7** indicating process in a UTS frame, where at step **520** a sync **1** signal is transmitted on the access channel at the settings determined as step **518**. Then at step **522** the base station proceeds from step **504** through connector "C" to check for any received sync **1** signals. If none are received, either because the remote terminal is out of range or did not transmit a sync 1 signal due to returning to step **502** from either steps **510** or **516**, then the base station returns to step **500** through connector "A" to continue generating access channels on DTS frames. The remote terminal powers the transmitter off for the sync 2 field, step **524**, and then powers the transmitter on to transmit a link request signal on the UTS access channel, step **526**. The link request signal may include the PID of the remote terminal and any priority of a call originating at the remote terminal. Meanwhile, the base station processes the received sync **1** field and determines if more than one remote terminal transmitted a sync **1** signal a step **528**. If true, step **530** selects an optimal sync **1** for further processing. Step **530** is defined in more detail at FIGS. **10** and **11**. Then at step **532**, it is determined if the link request signal sent of step **526** is correctly received. If received, the base station performs an estimate of the spacial signature, determines course adjustment of sync shift and power control and determines an available traffic channel at step **534**. If incorrectly received, the link request is partially detected, course sync shift and power control is done on the basis of the received signal at step **536**. This step is likely executed as a result of a link request collision where more than one remote terminal is attempting to establish communication with the base station. The partial detection is a result of a selected sync **1** at step **520**, but an errored CRC, or other detection of poor signal quality, at step **532**.

Note that in the event of a high priority call, such as a user dialing "911", the invention provides a method of establishing communication between a remote terminal and a base station in a communication system for communicating between the base station an a plurality of base stations comprising the steps of: receiving a call signal from a user of the remote terminal indicative of a request to originate communication between the remote terminal and the base station, step **510**; determining a priority of the call signal, step **512**; transmitting a first priority link request signal in response to the call signal having a first priority, step **526**; or determining if the base station has an available channel and generating a channel available signal in response to the call signal having a second priority, step **514**; and transmitting a second priority link request signal, step **526**, in response to said available channel determination.

From step **534**, the process of the base station proceeds through connector "E" to FIG. **8**, which indicates processes in a subsequent DTS frame, step **540** again transmits the training signal. The remote terminal proceeding from step **526** through connector "G" to step **542** to again receive the training signal on the access channel. Then in step **544**, the base station transmits a directional link grant signal on the access channel, the direction being determined in response to the spacial estimate of step **534**. Alternatively, the link grant signal can be omnidirectional. The link grant signal includes a frame, B/I and a control signal having a PID of a remote terminal, course sync shift and power control signals and an index of a traffic channel to be used by the remote terminal. If in step **545** the PID received by the remote terminal matches the PID assigned to the remote terminal, then the remote terminal uses the course sync shift and power control signals and the traffic channel communicated by the base station. And the remote terminal enters the traffic mode at step **548**.

An exception is the process of handling a priority call originated at the remote terminal when no traffic channels are available. Step **544** then transmits a link grant signal but provides a channel index corresponding to the access channel, preferably index zero. In response to which the remote terminal recognizes the index of zero and remains monitoring the access channel in interim DTS frames until the base station, in step **544**, transmits a link grant signal assigning the remote terminal to an available traffic channel. In the interim DTS frames, the base station may actively terminate a low priority call to make a traffic channel available for the priority call. Methods of determining a low priority call include prioritizing calls relative to length of call, and assigning a lower priority to longer calls. Or based upon a predetermined priority assigned to remote terminals or destinations coupled through the traffic channels, or the type of information communicated where FAX information could have highest priority, and voice a lower priority, and low content voice have large silent times having the lowest priority.

Alternately, the process of the base station proceeds through connector "F" of FIG. **7** to again transmit a training signal **550** which is processed by the remote terminal in step **542**. Thereafter at step **554**, because the link request was partially detected at step **536**, the base station continues transmitting the access channel in the wide area mode including frame and B/I information, the control signal is sent without a "link grant" signal, this is indicative of the partial detection, and sends a course sync shift and power control in response to the sync **1** signal selected at step **530**. The access channel signal of step **554** is received by the remote terminal at step **545**. If the transmission, received at step **545** is by either step **554** or step **544**, had the PID of another remote terminal, then the remote terminal proceeds to step **556** to determine if a link grant signal was sent. If not, the transmission was from step **554** and the remote terminal uses the course sync shift and power control signals of step **554** in the next attempt to establish communication at step **518**. Note that the use of power control at step **536** is optional and not essential and an alternative embodiment may have no estimation of power control in which case the remote terminal would not perform a power adjustment in response to step **536**. If a link grant not intended for the remote terminal is received at step **544**, then the sync shift and power control information is ignored and link establish-

ment remains pending at the next execution of either step **508** or **510**. From either step **556** or **558**, a random number of frames are delayed at step **560** before a subsequent attempt is made to establish communications between the remote and base station by a subsequent execution of step **502** through connector "B". The base station returns from either steps **544** or **554** to step **500** through connectors "A" to continue generating DTS access channels.

FIG. **9** shows the operation of the base station and the remote terminal communicating on a traffic channel. Steps **600–614** represent a DTS frame and steps **620–630** represent a UTS frame. The base station, in step **600** transmits a training signal on the access channel, and the remote terminal receives the training signal on the access channel in step **602**. Step **600** corresponds to steps **500** and **540**, while step **602** corresponds to steps **502** and **542**. The base station then enables the traffic channel and the corresponding beam forming at step **604**. Then the frame number, fine sync shift and power control is transmitted at step **606**. The remote terminal switches from processing the access channel to processing the traffic channel assigned to the remote terminal at step **608**. At step **610** the fine sync shift and power control is received and readied for use in the next UTS transmission. Thereafter in step **612** the base station transmits the traffic information or control information, which is received and processed by the remote terminal at step **614**.

A remote terminal enters the traffic mode from step **548** of the access mode at step **620**. At step **620** the remote terminal is configured to send a link initialization signal in the first UTS frame. From either step **614** or **620**, the remote powers the transmitter off during sync **1** at step **622**. This has the advantage of allowing the remote terminals to attempt to access the base station in any UTS frame during sync **1** at step **520** without interference from remote terminals on the traffic channels. Step **624** checks if the frame number of the current UTS frame corresponds to a signal indicative of a frame number assigned to the remote terminal by the base station. Preferably an index signal in the link grant signal from the base station indicates both the code channel and frame number to be used in the traffic mode. If there is no match, the remote terminal keeps the transmitter powered off during sync **2**. If there is a match then the remote terminal powers on the transmitter and transmits a sync **2** signal. This method assures that only one remote terminal transmits a sync **2** signal at a time. This has the advantage of enabling improved spacial estimates, sync shift and power control by the base station during sync **2**, step **626**, because interference from transmissions by other remote terminals is significantly reduced during sync **2**. Then the remote terminal transmits corresponding traffic or control information at step **628**. This is received and processed by the base station at step **630**. At step **630** the base station also updates the spacial signature, sync shift and power control, albeit with some interference from other remote terminals concurrently transmitting on other traffic channels at step **628**. Thereafter, the base station returns to step **600** though connector "J" and the remote terminal returns to step **602** through connector "K" to begin again with a DTS frame.

An advantage should be noted that reduced interference of the sync **2** signal is also helpful in resolving a problem with a remote terminal that is loosing synchronization with the base station on the UTS frames. If the timing of the UTS traffic signal is beyond a certain detection range, but for the sync **2** signal, the base station could measure the traffic signal as low in power at step **606** when in fact the signal has the correct power but incorrect sync shift. In response the base station could erroneously signal the remote terminal to increase the transmission power. The increased power increases the interference with transmissions received from other remote terminals, in which case the base station could signal the other remote terminals to also increase their transmit power. Eventually this builds into an undesirable situation where remote terminals are transmitting with excessive power. The sync **2** transmission control in accordance with the present invention helps resolve this problem by reducing the interference when measuring each remote terminal. Furthermore, since only one of the thirty one access channels is being processed, additional DSP resources are available to increase in ability to detect remote terminals going out of sync than may be available when processing access or control information sent at step **628** by multiple remote terminals.

FIGS. **4** and **6** through **9** show a communication system having a plurality of frames **304** and **308** for communication from a plurality of remote terminals to a base station on a common carrier having a plurality of concurrent code channels, each frame having a first portion corresponding to sync **1** **364** and empty **384** for first synchronization, a second portion for second synchronization corresponding to sync **2** **386** and empty **366**, and a third portion corresponding to signals **370**, **395** and **397** for communicating information from the remote terminals to the base station. A method in a remote terminal comprising the steps of: acquiring a CDMA communication channel with the base station by, enabling the transmitter at step **520** and communicating a first synchronization signal during the first portion, disabling the transmitter at step **524** during the second portion, and enabling the transmitter at step **526** and communicating information including an identification signal unique to the remote terminal in the third portion; and in response to a signal at step **544** from the base station granting a CDMA communication channel, maintaining the communication channel by, disabling the transmitter at step **622** during the first portion, enabling the transmitter at step **624** and communicating a second synchronization signal during the second portion, and enabling the transmitter at step **628** and communicating message information during the third portion.

FIGS. **4** and **6** through **9** show a communication system having a plurality of frames **304** and **308** for communicating traffic information from a plurality terminals to a base station on a plurality of concurrent code channels having a common carrier frequency, each frame having a first and second portion corresponding to sync **1** **364** and sync **2** **386**. In the base station a method of improving a spacial signature estimate for each of the remote terminals comprising the steps of: enabling transmission of a synchronization signal by a first remote terminal in the first portion of a first frame at step **544** and **606**; inhibiting transmission of a synchronization signal by a second remote terminal in the first portion of the first frame, such as a second terminal concurrently executing step **622** while the first terminal is executing step **520**; and estimating a spacial signature for the first remote terminal during the first portion of the first frame at step **534**.

FIG. **10** shows a flow chart representing selection of an optimal sync I reception of step **530**. FIG. **11** illustrates relative timing and power levels used for selecting one of several concurrent sync **1** signals in accordance with the present invention. At step **650** a check is made of all sync **1** signals received, each sync **1** signal received is measured relative to received power and timing of reception. FIG. **12** shows four received sync **1** signals of various power level and timing, **702**, **704**, **706** and **708**. Rectangle **700** represents

an power/time area above which a sync 1 signal is desirable. Sync 1 signal **702** is above the desirable level P within the desirable time, −T and +T, and would be selected by step **650** of FIG. **11** at step **652**. If signal **702** were not present, then since no other signals are above rectangle **700**, signal **704** would be selected at step **654** because it has the highest power. If signals **702** and **704** were not present then signal **706** would be selected at step **654** because it has the highest power. If signals **702**, **704** and **706** were not present then signal **708** would be selected at step **654**. After selection, the timing offset of the selected signal may be used to further process the link request signal sent by the selected remote at step **525**. If signal **702** were present, then the sync shift signal would have a magnitude represented by arrow **710** which would place timing of the received signal at an optimal, and the power control signal would have a magnitude represented by arrow **712** which would place the power of the received signal at a determined optimum power. It should be noted that a similar method may be used to determine the sync shift and magnitude of each traffic channel received by the base station.

FIGS. **12** and **13** show various wide area and directional radiation patterns of a base station operation in accordance with the present invention. FIG. **12** shows an antenna array of the base station **50** in communication with remote terminals **10**, **20** and **30**. In a DTS frame, the antenna array transmits a wide area training signal having a radiation pattern corresponding to circle **900**. Thereafter, a wide area link access signal having a paging signal with a PID corresponding to remote terminal **10**. Concurrently with transmission of the wide area link access signal **900**, the base station transmits a directional traffic signal **910** to remote terminal **2**, **20** in order to facilitate a conversation between the user of remote terminal **2** and a destination. Advantageously, in the DTS frame of FIG. **12**, the base station concurrently transmits a wide area access channel and a directional traffic channel.

FIG. **12** shows a communication system for communicating information from a base station on a plurality of concurrent code channels modulated upon a common carrier frequency to a plurality of remote terminals, a base station having an antenna array **50** for selectively directing transmission of the code channels. A method comprising the steps of wide area transmitting an access signal **900** modulated upon a first of the plurality of code channels, and directionally transmitting a traffic signal **910** modulated upon a second of the plurality of code channels.

FIG. **13** shows the antenna array of the base station **50** in communication with remote terminals **10**, **20** and **30** in a subsequent DTS frame. The antenna array transmits a wide area training signal having a radiation pattern corresponding to circle **900** on the access channel. Thereafter a directional link grant signal **920** is transmitted to terminal **10** on the access channel. Concurrently with transmission of directional signal **920**, the base station transmits a direction traffic signal **910** to remote terminal **2**. Thus, in the DTS frame of FIG. **14**, the base station concurrently transmits a wide area training signal during a first portion of the access channel and switches from wide area to a direction link grant signal during a second portion of the access channel.

Therefore what is provided includes a smart antenna CDMA communication system which provides for a common frequency for both uplink and downlink communication and which enables improved spacial estimations of a remote terminal in order to improve the directional characteristics of a smart antenna. The communication system provides synchronous CDMA communication on both the uplink and downlink communication channels without adding significant cost or bandwidth to the communication system. The CDMA communication system provides for rapid establishment of a communication link between a remote terminal and a base station and efficiently addresses recovery from collisions. Furthermore, the communication system which reduces the channel capacity used to synchronize a remote terminal once a link is established.

We claim:

1. In a communication system having a plurality of frames for communication from a plurality of remote terminals to a base station on a common carrier having a plurality of concurrent code channels, each frame of the plurality of frames having a first portion, a second portion, and a third portion, a remote terminal comprising:

a controller for controlling operation of the remote terminal in an access mode and a traffic mode;

a first synchronization generator responsive to said controller for generating a first synchronization signal;

a second synchronization generator responsive to said controller for generating a second synchronization signal;

a data modulator responsive to said controller for generating modulated information signals; and

a transmitter coupled to said first synchronization generator, said second synchronization generator and said data modulator for generating a radio frequency modulated transmit signal indicative of the first and second synchronization signals and the information signals in response to said controller, wherein,

in the access mode, said controller enables said transmitter and said first synchronization generator in the first portion, disables said transmitter in the second portion, and enables said data modulator and said transmitter in the third portion during a first frame of the plurality of frames, and

in the traffic mode, said controller disables said transmitter in the first portion, enables said transmitter and said second synchronization generator in the second portion, and enables said transmitter and said data modulator in the third portion during a second frame of the plurality of frames subsequent to the first frame.

2. The remote terminal according to claim **1** further comprising

a receiver responsive to said controller for receiving base station information signals from the base station, wherein said controller switches from the access mode to the traffic mode in response to a link grant signal included within the base station information signal.

3. The remote terminal according to claim **2** further comprising:

a user information input means responsive to said controller and coupled to said transmitter for receiving information from a user of the remote terminal and for generating user information signals in response thereto, wherein

said data modulator generates modulated information signals uniquely identifying the remote terminal in response to the acquisition mode, and generates modulation information signals indicative of the user information signals in response to the traffic mode.

4. The remote terminal according to claim **2** further wherein

said receiver generates a received power signal indicative of the power level of a training signal received from the base station, and further comprises

a synchronization shift adjustment means responsive to said controller and coupled to said receiver and said first synchronization generator for adjusting a timing of transmission of the first synchronization signal with the first portion in response to the received power signal.

5. The remote terminal according to claim 2 wherein the base station information signals include a frame number signal uniquely identify each frame as one of set of periodically repeating frames, wherein during the access mode, said controller inhibits said transmitter if the frame number signal of the first frame does not match a predetermined value.

6. The remote terminal according to claim 5 wherein said controller further includes a personal identification signal uniquely assigned to the remote terminal, and wherein the predetermined value is a function of the personal identification signal.

7. The remote terminal according to claim 5 wherein the predetermined value is a function of a signal received from the base station in a prior operation of the traffic mode by the remote terminal.

8. The remote terminal according to claim 2 wherein the base station information signals include a frame number signal uniquely identify each frame as one of set of periodically repeating frames, wherein during the traffic mode, said controller inhibits said transmitter during the second portion if the frame number signal of the second frame does not match a predetermined value.

9. The remote terminal according to claim 8 wherein the predetermined value is one of a plurality of predetermined values chosen in response to an index signal received within the base station information signals.

10. The remote terminal according to claim 1 wherein said transmitter further comprises

a spreading code modulator for increasing bandwidth of signals coupled into said transmitter, wherein said spreading code modulator spreads the transmitted signal in accordance with a first and a second spreading code signal during the access and traffic modes, respectively, wherein the first spreading code signal is predetermined and the second spreading code signal is selected in response to an index signal received within the base station information signals.

11. In a communication system having a plurality of frames for communication from a plurality of remote terminals to a base station on a common carrier having a plurality of concurrent code channels, each frame of the plurality of frames having a first portion for first synchronization, a second portion for second synchronization, and a third portion for communicating information from the plurality of remote terminals to the base station, a method in a remote terminal comprising the steps of:

acquiring a first of the plurality of code channels with the base station by,

enabling a transmitter within the remote terminal and transmitting a first synchronization signal during the first portion,

disabling the transmitter during the second portion, and

enabling the transmitter and transmitting access information including an identification signal unique to the remote terminal in the third portion; and

in response to a signal from the base station granting the first code channel, maintaining the first code channel by,

disabling the transmitter during the first portion,

enabling the transmitter and transmitting a second synchronization signal during the second portion, and

enabling the transmitter and transmitting message information during the third portion.

12. The method according to claim 11 further comprising the step of:

determining a received power level of a synchronization signal received from the base station; and

said step of acquiring further comprises the step of shifting synchronization timing of the access information in response to the received power level, and

said step of maintaining further comprises the step of shifting synchronization timing of the message information in response to a sync shift signal received from the base station and addressed to the remote terminal.

13. The method according to claim 12 wherein:

said step of acquiring further comprises the step of adjusting a power output of the transmitter in response to the received power level, and

said step of maintaining synchronization further comprises the step of adjusting the power output level of the transmitter in response to a power control signal received from the base station and addressed to the remote terminal.

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